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NOTES ON THE STRUCTURE AND MOVEMENT OF THE WAVE DEPRESSION WHICH MOVED ACROSS THE BRITISH ISLES ON 7 NOVEMBER 1979

by

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Reference

October 1980

N.B. This paper has not been published. Permission to quote from it must be obtained from the Assistant Director in charge of the above Meteorological Office Branch.

Notes on the structure and movement of the wave depression which moved across the British Isles on 7 November 1979

Introduction

This analysis was undertaken as part of a joint project between Met O 11 and the Radar Research Laboratories (METORRL) at Malvern. Only the synoptic content of the situation, together with cross-section analyses, plus a selection of the output from the current 10-level Model (Rectangle forecasts) covering the day concerned, are included here. The document is intended to serve as a basis for further co-operation with METORRL over aspects of radar coverage analysis. It is hoped that certain areas of investigation may be pointed to as a result of the main deficiencies of the Rectangle forecasts being highlighted in this paper.

1. Synoptic situation

In the upper air a strong westerly flow was evident at around 55°N across the Atlantic (see Fig. 1d), turning ESE'wards on the western side of a trough over Europe. A suggestion of slight ridging over, and ahead of, the surface wave can be seen from the 500 mb chart for 12 GMT on 7 November (Fig. 1d). The strongest winds at 500 mb (80 kt plus) coincided with the track of the surface wave centre (Fig. 2a).

At 06 GMT on 7 November (Fig. 1a), there was a weak surface ridge over central and eastern England, with a warm front link through the ridge from Paris, through Exeter, Milford Haven, Rosslare and Galway, out to the developing wave centre at 55°N 14°W. Cold air was pushing down from the northwest on the western side of the wave, and a double-structure was analysed, based on higher dewpoints and confirmed later by observations over England (Fig. 3). By 12 GMT the wave centre had deepened to 990 mb over Cavan (Eire) and the northern warm front had pushed on to a line through Liverpool and London. Later in the day the inner warm sector became ill-defined, so that by 18 GMT (Fig. 1c) the analysis was simplified to one set of fronts with the wave tip near the Wash and a cold front through the Thames Estuary, east of the Isle of Wight and out to 49°N 5°W.

The time sequence of synoptic observations (Fig. 3) shown at 3-hourly intervals brings out the following points:-

a. The Scilly Isles had at least a 15-hour period of warm-sector conditions, with intermittent light rain or drizzle, occasional poor visibility, layered stratus and stratocumulus cloud. Winds were between SW and W, 15 to 25 kt, veering to NW in the cold air.

b. At Exeter the period of poor weather conditions was much shorter than that at Scilly. Note that the surface wind at Exeter backed to well east of south ahead of the inner warm front.

c. Lyneham experienced a 4 to 5 hour period of low stratus, rain and drizzle, but further northeast, at Cardington, stratocumulus and medium cloud dominated the period between 03 and 21 GMT, with a period of continuous slight rain during the afternoon and very little low cloud.

d. The moderate rain at Coltishall at 15 GMT was produced by the combined effect of the main warm front, together with the rapid approach of the wave centre.

e. At Manston, enjoying a certain amount of shelter from southwesterly winds, the amount of low stratus was limited, whilst the moderate rain occurred only for a short time on the warm front. Similar conditions were experienced at Heathrow, but at an hour or so earlier than at Manston.

Turning now to details of the rainfall which occurred over UK during the period 09 GMT 7 November to 09 GMT 8 November, let us first examine the rainfall map covering that 24-hour period (Fig. 4). This small version was copied from a computer-plotted 1 : 2,000,000 scale map produced using a Met O 8 program. At the time that the program was run, not all observing/recording errors had been quality-controlled out; stations with errors were ignored in the subjective hand-drawn analysis. It can readily be seen from the map that there are two main reasons for the rainfall distribution:

1. Orographic effects, with the heavier rainfall in western Scotland, northwest England, Wales and over Exmoor.

2. A band of heavier falls (10 mm or more) shown in Northern Ireland, Cheshire, across the south Pennines to Norfolk, in association with the wave tip as it travelled east-southeastwards across the country.

Of interest is a second, broken, band of slightly higher rainfall, with the same orientation, across Somerset, central southern England as far as east Sussex. This could be credited partly to the track of the inner wave centre (Fig. 2a) and partly to a phenomenon, documented by Harrold (1973), of rainbands 'streaming' downwind from areas of high ground.

The maximum 24-hour rainfall totals plotted on the Met O 8 chart were 38 mm in the vicinity of Snowdon, 34 mm over the Brecon Beacons, and 29 mm over the south Pennines. Figure 5 gives an idea of the distribution of rainfall with time across the Country. Bearing in mind that moderate rain is defined as occurring at a rate greater than 0.5 mm/hr it can be seen that the moderate rain fell at Aldergrove between 08 and 12 GMT and 13 and 15 GMT, at Manchester between 11 and 18 GMT, Benson between 11 and 13 GMT and between 14 and 15 GMT, and at Marham between 12 and 16 GMT - in fact heavy rain (a rate greater than 4.0 mm/hr) occurred between 14 and 15 GMT at Marham. It is interesting to note that the moderate rain ceased at Aldergrove, Benson and Marham within an hour of each other, whereas the moderate rain continued until 18 GMT at Manchester - probably due to local effects and the marked cyclonic curvature remaining over that area, even at 18 GMT (Fig 1c).

Figures 6a to 6d depict the areas of moderate rain, based solely on the small synoptic network, at 09, 12, 15 and 18 GMT. It can be seen, however, how rapidly development took place between 09 and 12 GMT, and how, at 15 GMT, the moderate rain became aligned with the main warm front. By 18 GMT a 'backwash' effect seems to be attributable to the factors of marked cyclonic curvature mentioned above, and an additional feed of moist air from the North Sea (Figs 1c and 6d) which, by that

time, would have been lifted several hundreds of feet over the Yorkshire Wolds and eastern slopes of the Pennines. The effects of the inner wave can be seen, especially, on the map for 15 GMT (Fig. 6c), with a significant area of moderate rain over Hampshire, Surrey, Sussex and the eastern Channel.

2. Cross-section analyses

The cross-section of upper winds and temperatures at 12 GMT shown in Figure 7 is taken along the line AB marked on Figures 1b and 1d. Isotachs (drawn at 10 kt intervals) show clearly that the strongest winds in the jet were at about 250 mb with a double core: one at $52\frac{1}{2}^{\circ}$N and the other much further south at 48°N. Lower down, at 500 mb, the jet can be located over Long Kesh, coinciding with the track of the main wave.

A frontal surface is apparent from the surface, between Camborne and Valentia, and, at about 400 mb, over Stornoway, along the line of greatest wind-shear. It may be more than just a quirk in the drawing of the isotachs that a double-structure can be inferred from Fig. 7 - the inner warm front at 700 mb between Long Kesh and Shanwell, and the main warm front at 500 mb between Shanwell and Stornoway.

The temperature structure, somewhat disappointingly, does not readily indicate a great deal of information, other than to confirm the heights of the tropopauses in relation to the jet. The cross-section of wet-bulb potential temperatures (Fig. 8), (θ w) drawn for the same time and orientation as that in Figure 7, gives a good idea of the airmass changes across the Country. Values of 16°C are shown at about 400 to 450 mb above Brest, falling sharply to 8°C at 850 mb over Valentia, and steadily to 2°C below 850 mb from Shanwell northwards. A maximum gradient of θ w can be seen in Figure 8, which roughly corresponds with the region of maximum wind-shear in Figure 7. Figure 9 presents the spatial variation of θ w at 850 mb and shows the strong gradient over East Anglia and Kent at 12 GMT.

3. The Rectangle Model forecasts

Two computer runs of the Rectangle Model, covering the period 06 to 18 GMT on 7 November, have been studied: 1. based on data time 12 GMT on 6 November

and 2. based on data time 00 GMT on 7 November. Figures 2b and 2c show the tracks of the system as predicted at 12 GMT on 6th and 00 GMT on 7th. These can be compared with the actual tracks of the main and inner waves given in Figure 2a. It seems that, in the earlier run, the model 'got hold of' the inner wave tip or, what is more likely, that the predicted track was a compromise between the main and inner wave tracks. 12 hours later, however, the predicted track was much further north, a little further north in fact, than even the main wave. In both runs the wave depression was moved too quickly, leading to an error, by 00 GMT on 8th, of about 4 degrees longitude (approx 250 km 36 hours and 24 hours, respectively, after data times), although the later forecast based at 00 GMT on 7th was marginally better than the earlier forecast.

In order to simplify analysis of the Rectangle Model output, only the predicted wave tracks, predicted moderate rainfall areas at 6-hourly intervals from 06 to 18 GMT, and predicted accumulated rainfall totals (estimated by interpolation), are documented here. A more comprehensive set of forecast charts is included in the Appendix. (In addition to these data, the original charts prepared during analysis of the situation are held in Met O 11, but items like the Met O 2 hourly British Isles charts and circumpolar charts are held in Met O 18 (Archives).)

Figures 10a to 10c show the predicted moderate rainfall areas at 06, 12 and 18 GMT, based on data time 12 GMT on 6th. Each circle represents moderate rain at a grid point; grid points are at approximately 100 km intervals. Comparing these maps with those in Figure 6, it can be seen that the model carried the moderate rain area across the country too quickly. By 12 GMT moderate rain was predicted in the English Channel, East Anglia, and southeastwards across the Netherlands, Belgium and Germany, whereas, as Figure 6b shows, the actual area of moderate rain had only reached northwest England, central and eastern Wales and the Midlands. Reference to Figures 10c and 6d indicate that the residual rainfall over Yorkshire and north-east Norfolk at 18 GMT was not predicted.

Figures 10d to 10f show the predicted moderate rainfall areas at 06, 12 and 18 GMT, based on data time 00 GMT on 7th. Again, comparing these maps with those in Figure 6, it is apparent that the timing was still too fast - by a lesser amount - the predicted area for 12 GMT (Figure 10e) coinciding fairly closely with the actual area at 15 GMT (Figure 6c), but incorrectly forecasting a further area of moderate rain over France. It is interesting to note that this later run produced a greater residual rain area over the North Sea for 18 GMT, (Figure 10f), but it was not extended sufficiently far back towards Yorkshire (compare Figure 10f with Figure 6d).

Figure 11 contains estimated accumulated rainfall predicted by the 10-level Rectangle Model for the 24-hour period 09 GMT 7 November to 09 GMT 8 November. As the original maps were produced for 6-hourly intervals, values from 09 to 12 GMT on 7th and from 06 to 09 GMT on 8th had to be estimated by interpolation. Only the forecast based on data time 00 GMT on 7th is considered here as a direct comparison may be made with the actual rainfall distribution map (Figure 4) covering the same period (the forecast based on the earlier data time of 12 GMT on 6th had a large timing error, making comparison impracticable). It can be seen that the general pattern of rainfall distribution predicted was quite good but with the following deficiencies:-

a) a shortfall of 50% in totals across the main rainband from Northern Ireland to Norfolk (it is accepted that the orographic enhancement of rainfall over the Pennines would not be well predicted due to the topographic smoothing inherent in the model),

b) a marked shortfall over the higher ground in western UK.

4. Conclusion

The main points which come out of this study of the movement of a wave depression across the British Isles are:

1. The system had a double-structure - a main warm and cold front through the wave

tip and an inner warm sector of higher dew-point surface air.

2. The wave travelled ESE'wards across Northern Ireland, the southern Pennines and along the coast of Norfolk, along a track coinciding with the 500 mb jet of 80 kt.

3. The main areas of moderate rain were associated with the northern warm front, together with a band, some 70 km wide, along the line of the track of the centre of the wave. In addition, orographic enhancement of rainfall occurred over western UK and over the southern Pennines.

4. The Rectangle Model forecasts covering the period 06 to 18 GMT (during which most of the moderate rain fell), based on data times 12 GMT 6 November and 00 GMT 7 November, respectively, contained the following errors:

a) both sets of forecasts moved the wave depression across too quickly - especially the earlier run,

b) the earlier run predicted a track too far south, possibly a compromise between the tracks of the main and inner waves,

c) insufficient orographic enhancement of rainfall was predicted,

d) rainfall accumulations along the line taken by the wave centre were forecast low by about 50%.

The next stage of Met O 11's work on this case study will involve re-running the numerical forecasts, varying basic model parameters such as the horizontal grid spacing, the number of levels in the vertical and the representation of topography, in order to examine how such variations affect the quality of the forecast, particularly from the point of view of the structure and movement of the main precipitation areas and the quantities of rain forecast. A further stage may involve the use of satellite-derived temperature and humidity data to define more accurately initial fields for the numerical model.

Reference

Harrold, T W 1973 Mechanisms influencing the distribution of precipitation within baroclinic disturbances. QJR Meteorol Soc, 99, 232-251.

Legends for Figures

Figure 1 Synoptic charts for 06, 12 and 18 GMT on 7 November 1979 (Figures 1a, 1b, 1c) and chart for 500 mb at 12 GMT on 7 November 1979. The position of the cross-sections drawn in Figures 7 and 8 is noted on Figures 1b and 1d.

Figure 2 Figure 2a shows the actual track of the wave depression across the eastern Atlantic and into Europe. Figures 2b and 2c give the tracks of the wave as forecast by the Rectangle Model at data times 12 GMT 6 November and 00 GMT 7 November 1979. Also noted on Figure 2a is the track of the inner wave.

Figure 3 Time sequence of synoptic observations for 7 November 1979 at a selection of stations in southern England and East Anglia.

Figure 4 Accumulated rainfall (mm) over UK for the 24-hour period from 09 GMT 7 November 1979.

Figure 5 Hourly rainfall amounts (mm), in histogram form, at a selection of 4 climatological stations for the 24-hour period from 09 GMT 7 November 1979.

Figure 6 Areas of moderate rain, based on the synoptic network, over the British Isles at 09, 12, 15 and 18 GMT (Figures 6a, 6b, 6c and 6d).

Figure 7 Upper air cross-section, along a line SSW to NNE from Brest to Lerwick, at 12 GMT 7 November 1979, showing isotachs (kt), isotherms (^{o}C) and tropopauses.

Figure 8 Upper air cross-section, position as in Figure 7, showing wet-bulb potential temperatures (^{o}C) at 12 GMT 7 November 1979.

Figure 9 Chart of 850 mb wet-bulb potential temperatures over the British Isles at 12 GMT 7 November 1979.

Figure 10 Moderate rain areas, as forecast by the Rectangle Model for 06, 12 and 18 GMT on 7 November 1979. Figures 10a, 10b and 10c are based on data time 12 GMT 6 November 1979 and Figures 10d, 10e, 10f are based on data time 00 GMT 7 November 1979.

Figure 11 Accumulated rainfall (estimated), in mm, produced by the Rectangle Model for the 24-hour period from 09 GMT 7 November to 09 GMT 8 November 1979 (forecast based on data time 00 GMT 7 November 1979.

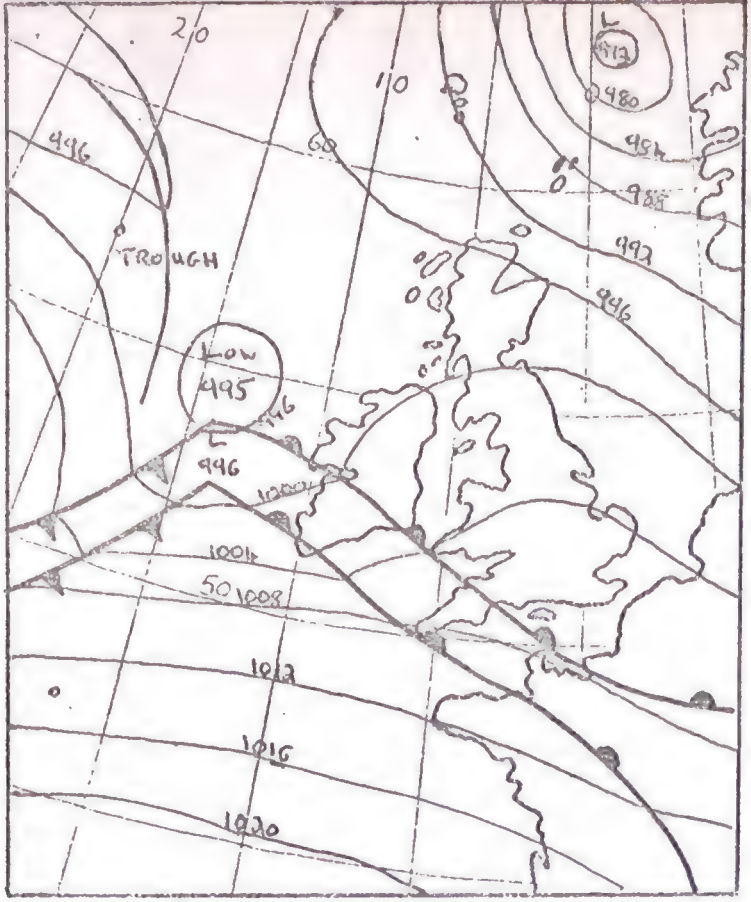


Figure 1a. Synoptic chart for 06 GMT on 7 November 1979.

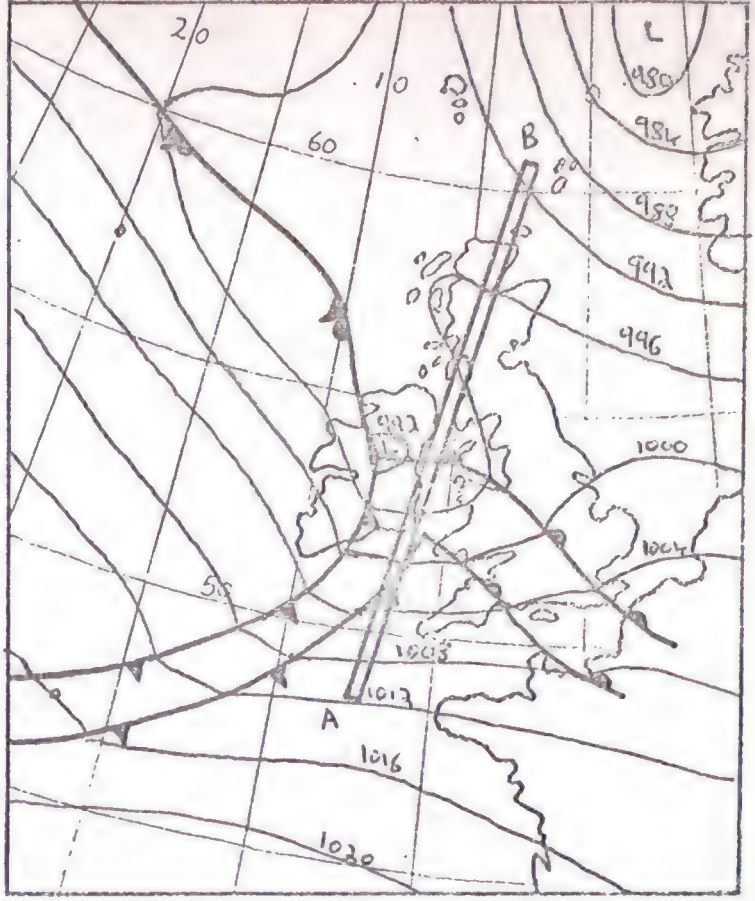


Figure 1b. Synoptic chart for 12 GMT on 7 November 1979, Line AB shows orientation of cross-sections in Figures 7 and 8.

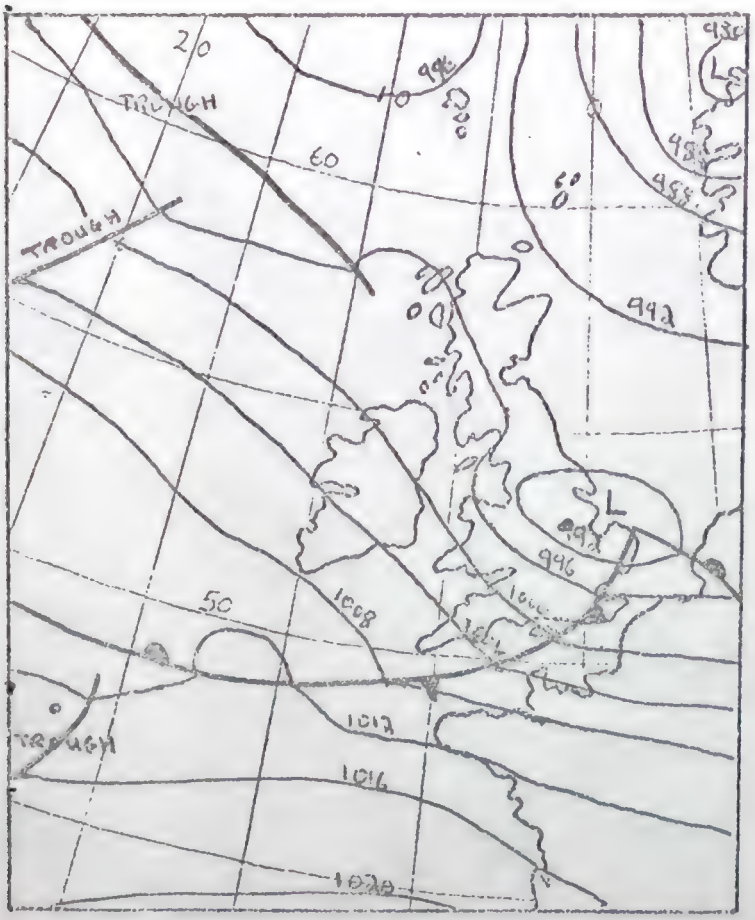


Figure 1c. Synoptic chart for 18 GMT on 7 November 1979

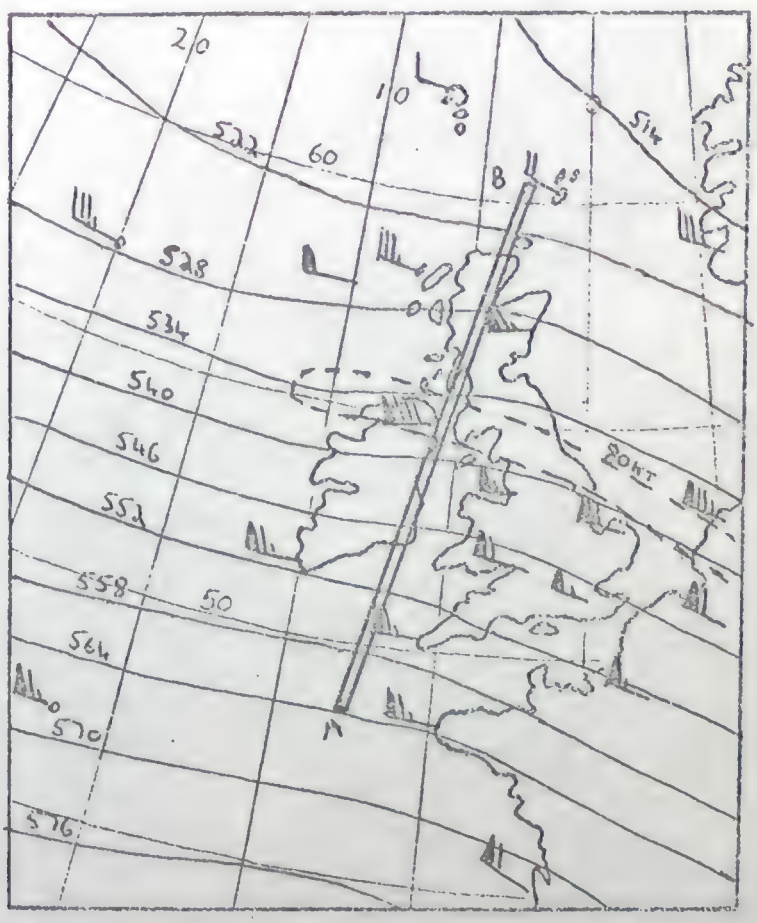


Figure 1d. Chart for 500mb at 12 GMT on 7 November 1979. Heights are in decageopotential metres. Line AB shows orientation of cross-sections in Figures

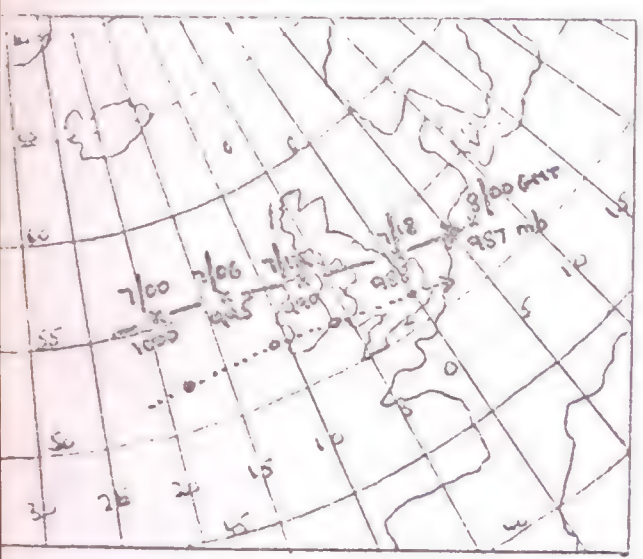


Figure 2a. Actual track of wave depression x——x and of inner wave o.....o with date/time positions.

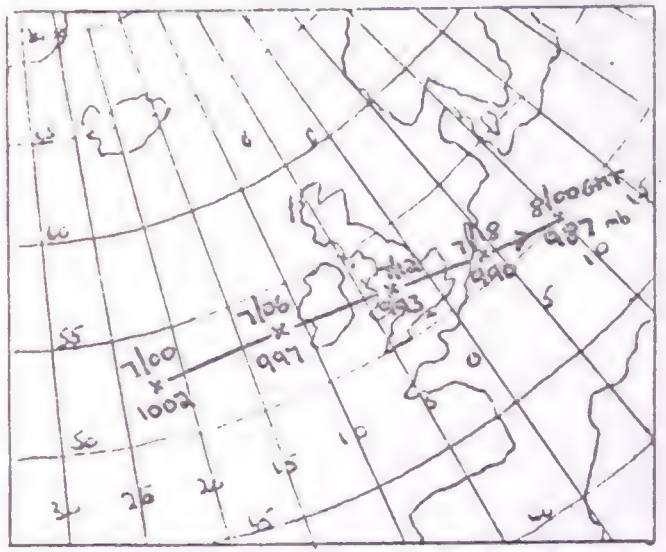


Figure 2b. Wave depression track, with central pressures, as forecast by Rectangle model for data time 12 GMT 6 November 1979.

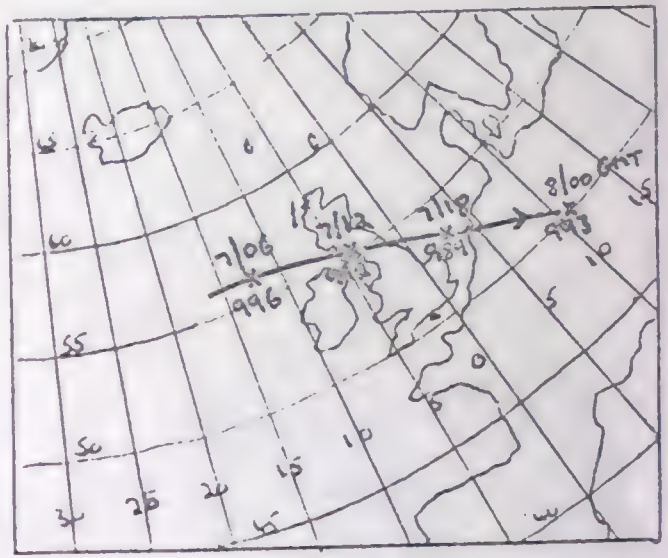


Figure 2c. Wave depression track, with central pressures, as forecast by Rectangle model for data time 00 GMT 7 November 1979.

Figure 3 . Time sequence of synoptic observations for 7 November 1974

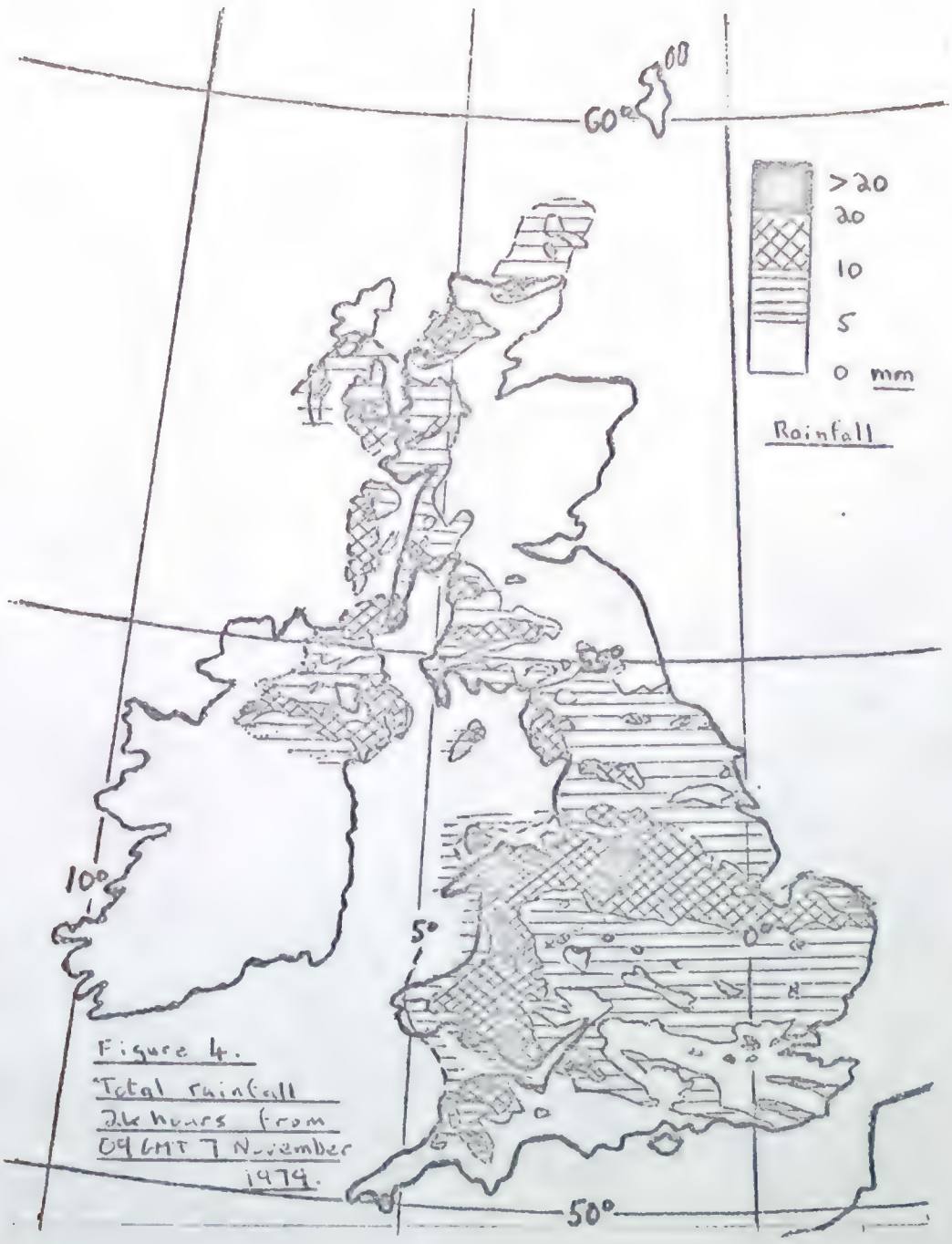


Figure 4.
Total rainfall
24 hours from
09 GMT 7 November
1979.

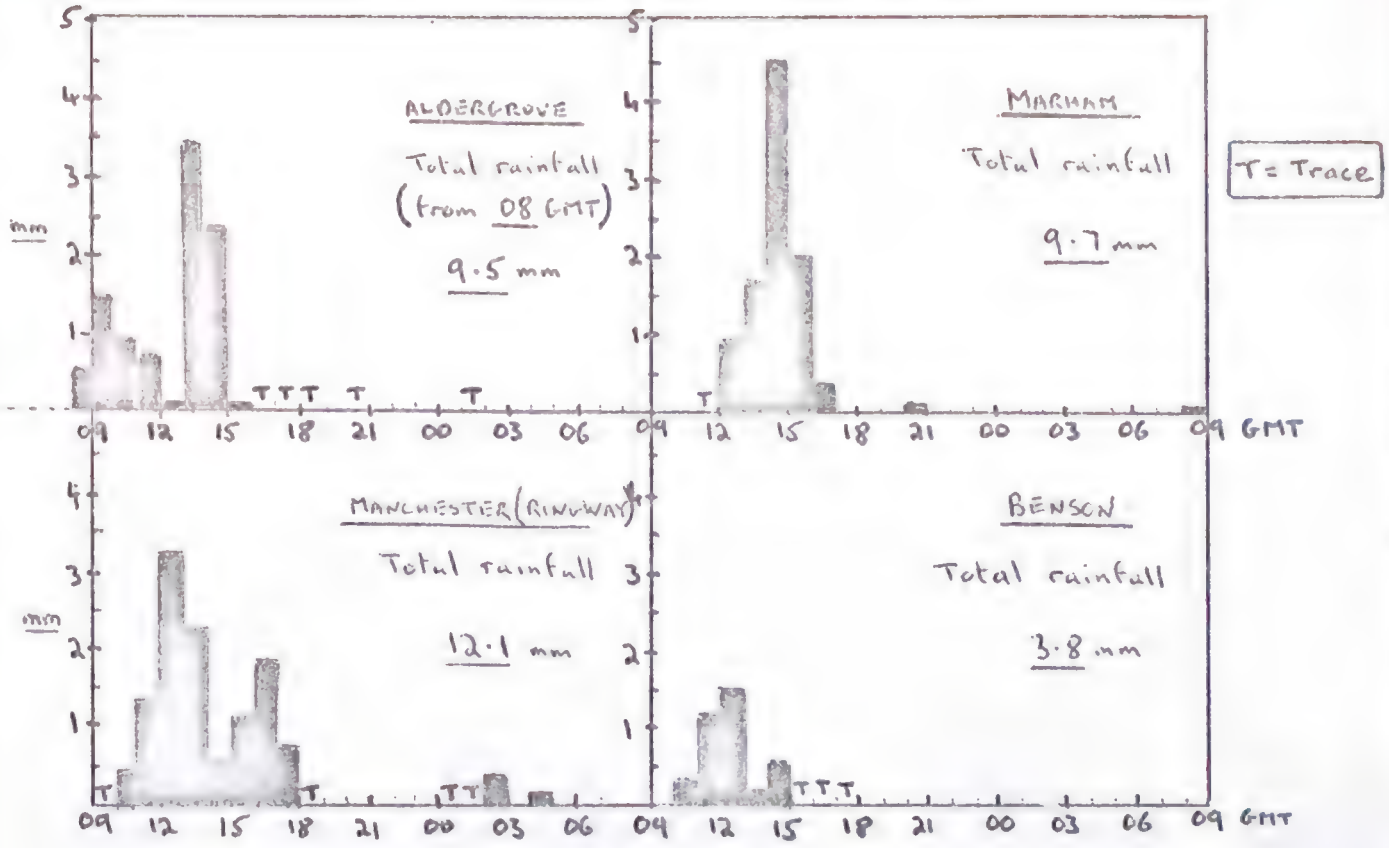


Figure 5. Hourly rainfall amounts at 3 stations (Aldergrove, Manchester and Marham) near track of main wave tip, and at Benson near track of inner wave tip, for 24 hours from 09 GMT 7 November 1979.

Figure 6a. Area of moderate or heavy rain based on synoptic network at 09 GMT.

Figure 6b. Area of moderate or heavy rain based on synoptic network at 12 GMT.

Figure 6c. Area of moderate or heavy rain based on synoptic network at 15 GMT.

Figure 6d. Area of moderate or heavy rain based on synoptic network at 18 GMT.

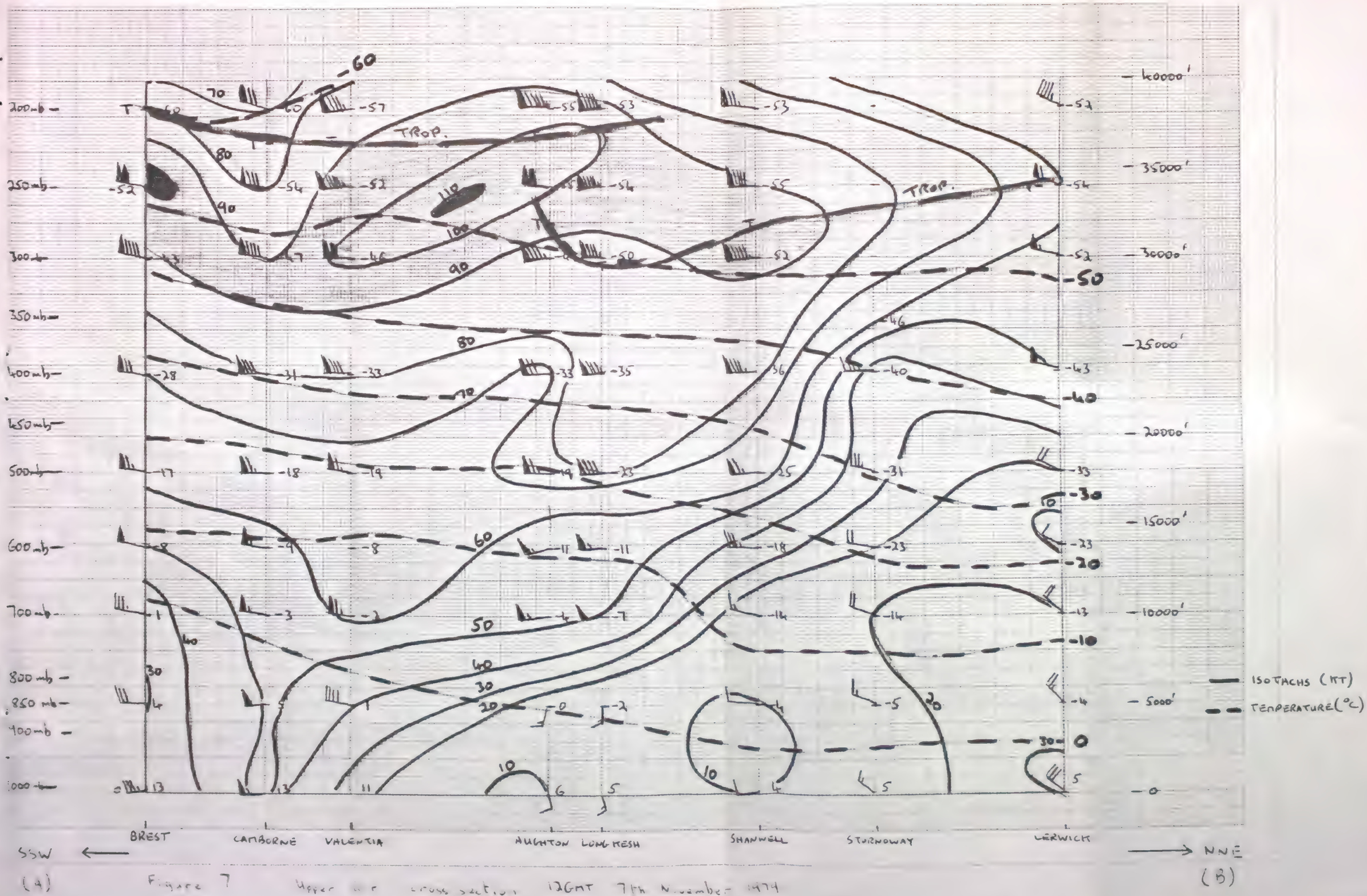


Figure 7 Upper air cross section 12GMT 7th November 1974

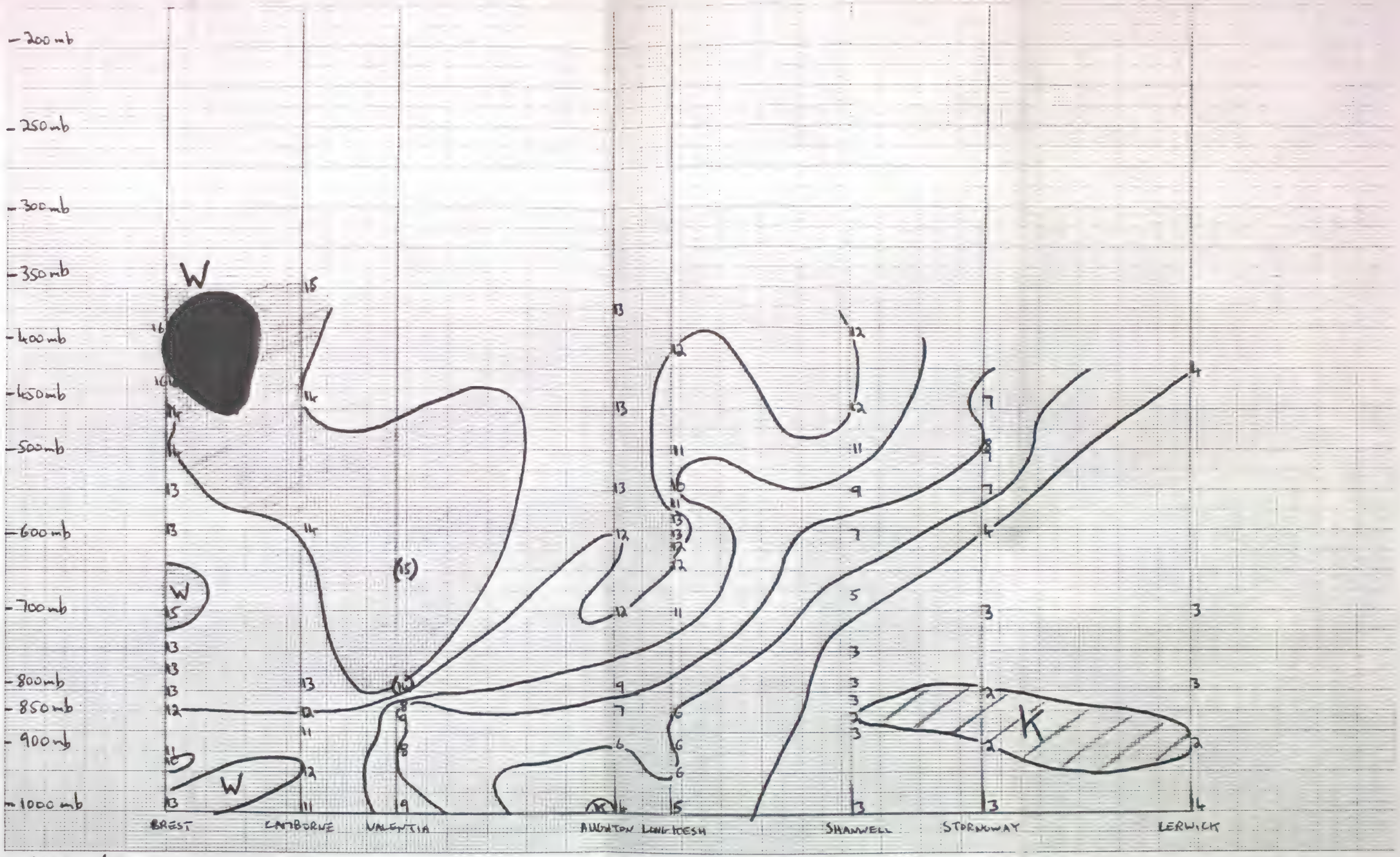


Figure 8. Cross-section of θ_w (°C) for 7 November 1979 at 12 GMT.

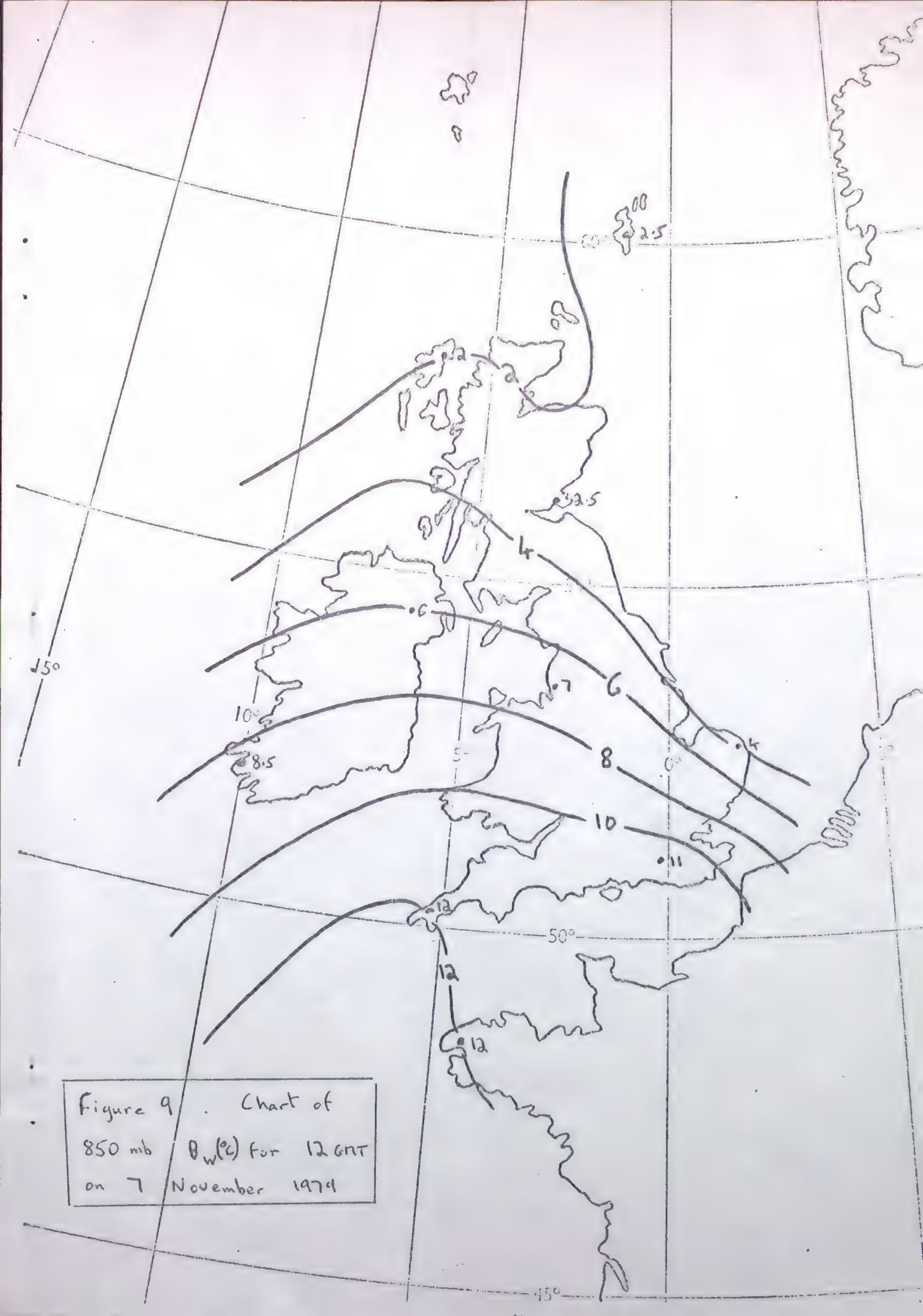


Figure 9. Chart of 850 mb θ_w(°C) for 12 GMT on 7 November 1974

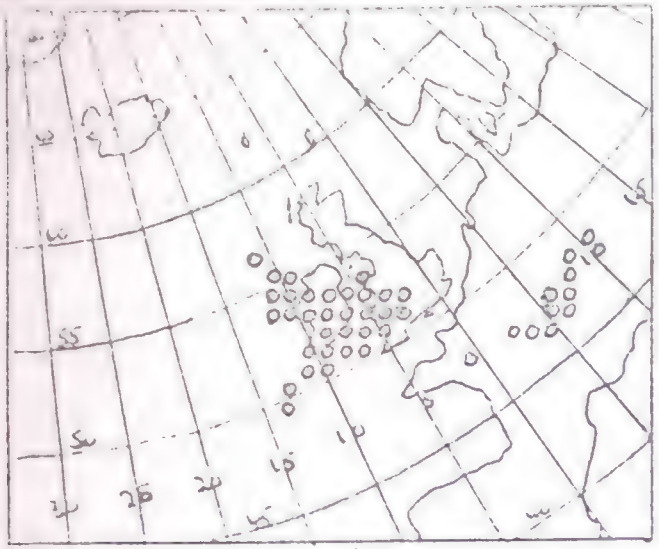


Figure 10a. Moderate rain area in 18 hour forecast produced by Rectangle model valid at 06 GMT 7 November 1979 (data time 12 GMT 6 November 1979).

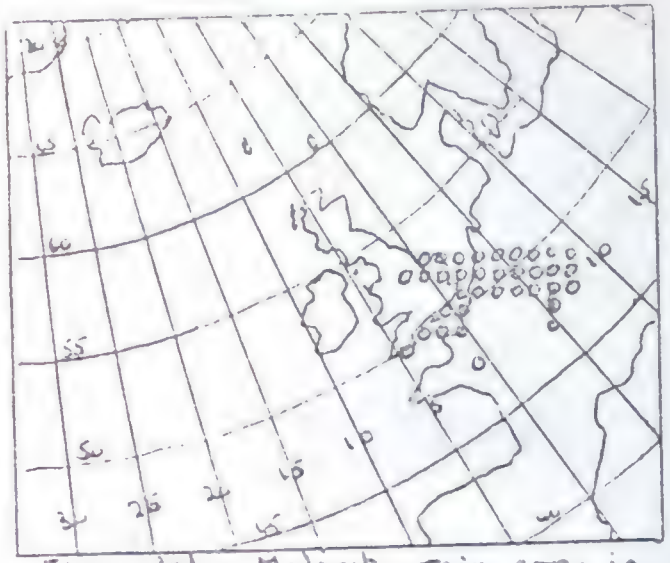


Figure 10b. Moderate rain area in 24 hour forecast produced by Rectangle model valid at 12 GMT 7 November 1979 (data time 12 GMT 6 November 1979).

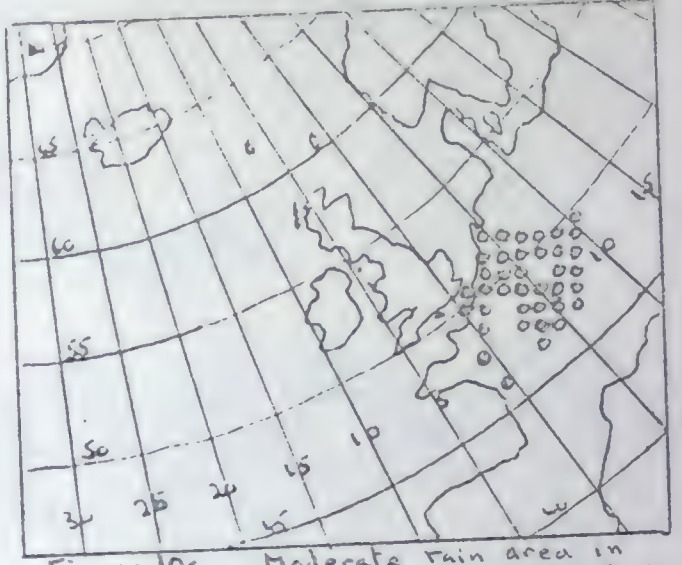


Figure 10c. Moderate rain area in 30 hour forecast produced by Rectangle model valid at 18 GMT 7 November 1979 (data time 12 GMT 6 November 1979).

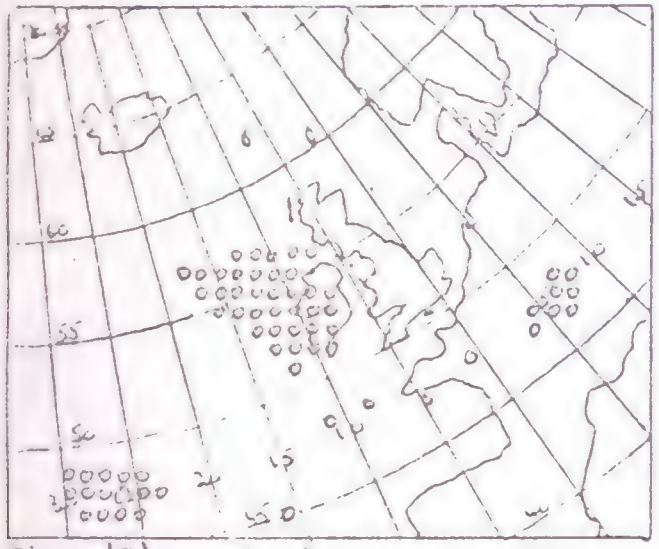


Figure 10d. Moderate rain area in 6 hour forecast produced by Rectangle model valid at 06 GMT 7 November 1979 (data time 00 GMT 7 November 1979).

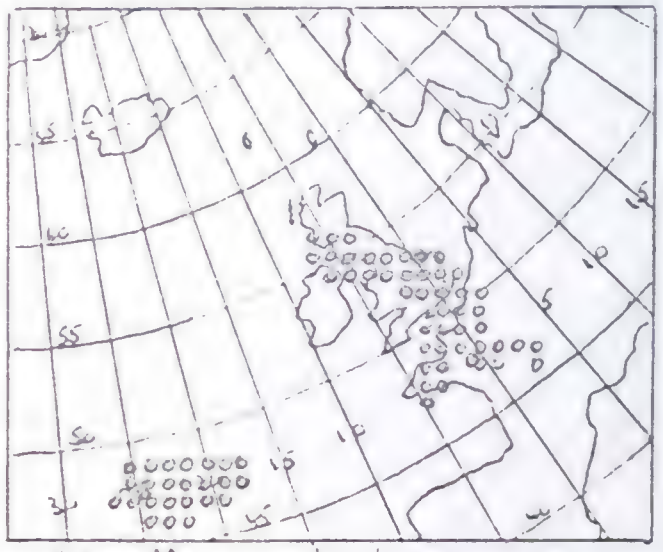


Figure 10e. Moderate rain area in 12 hour forecast produced by Rectangle model valid at 12 GMT 7 November 1979 (data time 00 GMT 7 November 1979).

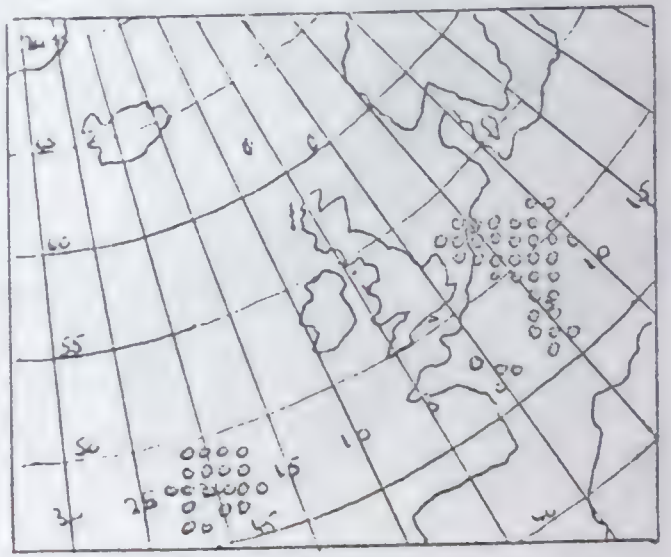


Figure 10f. Moderate rain area in 18 hour forecast produced by Rectangle model valid at 18 GMT 7 November 1979 (data time 00 GMT 7 November 1979).

Figure 11

10-level Model (RECTANGLE) Operational Forecast: accumulated rainfall (estimated), in mm, for 24-hr period up to 0900 GMT 8/11/79. (forecast based on data time 0000 GMT 7/11/79)

APPENDIX

Numerical Model Forecasts

The following chart output from the 10-level Model (fine-mesh Rectangle) is appended here :-

a. DATA TIME 1200 GMT 06/11/79.

500mb and surface pressure analyses.	T+0
Forecast surface pressure (with precipitation rates).	T+6 to T+36
Accumulated precipitation (over 6-h periods) forecast.	T+0 to T+36

b. DATA TIME 0000 GMT 07/11/79.

500mb and surface pressure analyses.	T+0
Forecast surface pressure (with precipitation rates).	T+6 to T+36
Accumulated precipitation (over 6-h periods) forecast.	T+0 to T+36
850mb wet-bulb potential temperature forecast.	T+6 to T+36
1000-500mb thickness forecast.	T+6 to T+36

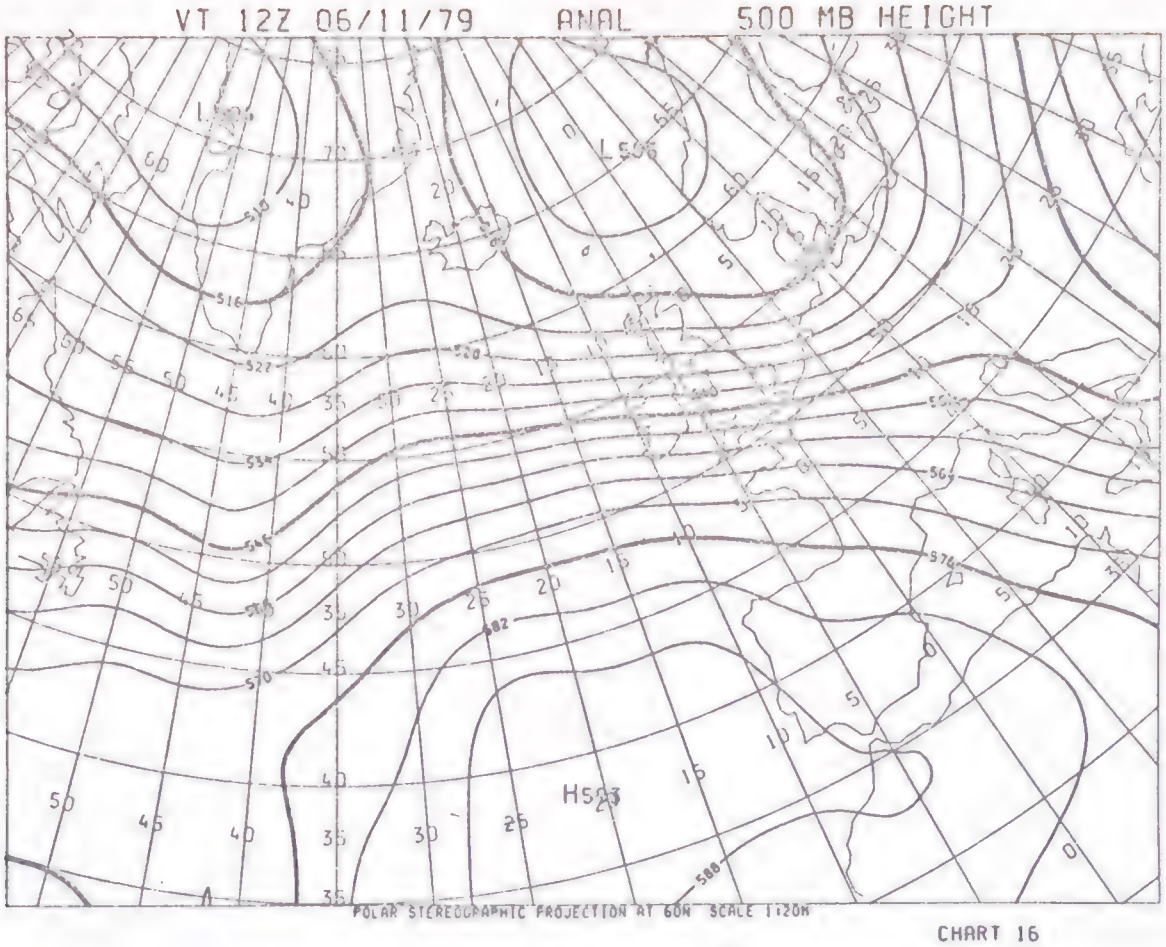


CHART 16

CFO

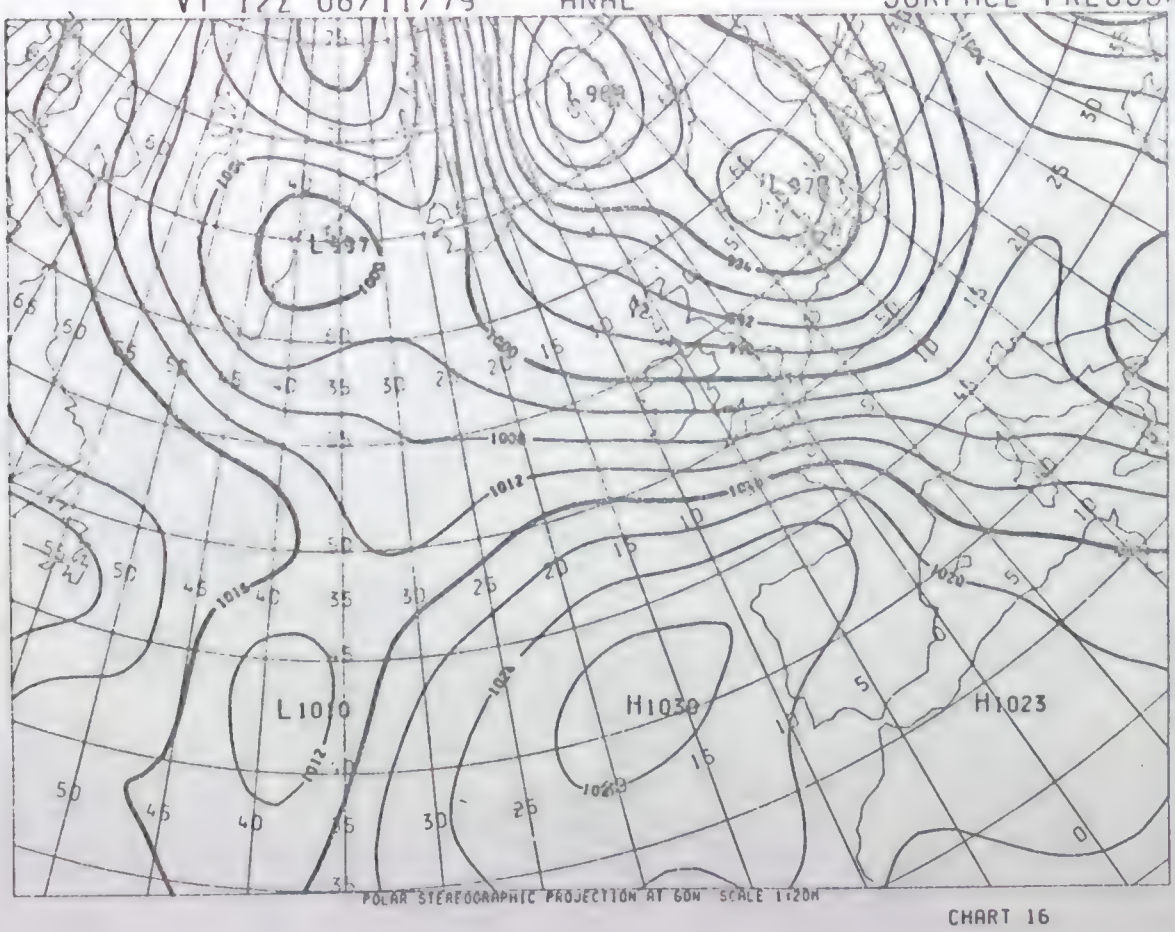


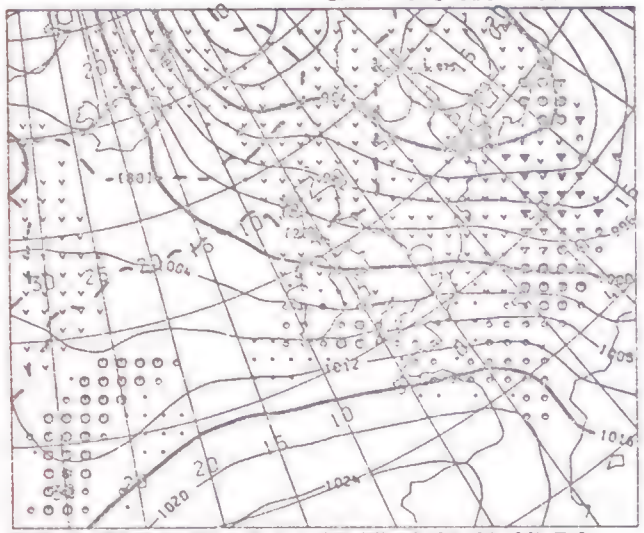
CHART 16

CFO

SURFACE PRESSURE AND PRECIPITATION

6HR FORECAST

VALID AT 18Z 6/11/79
DATA TIME 12Z 6/11/79



SURFACE PRESSURE AND PRECIPITATION

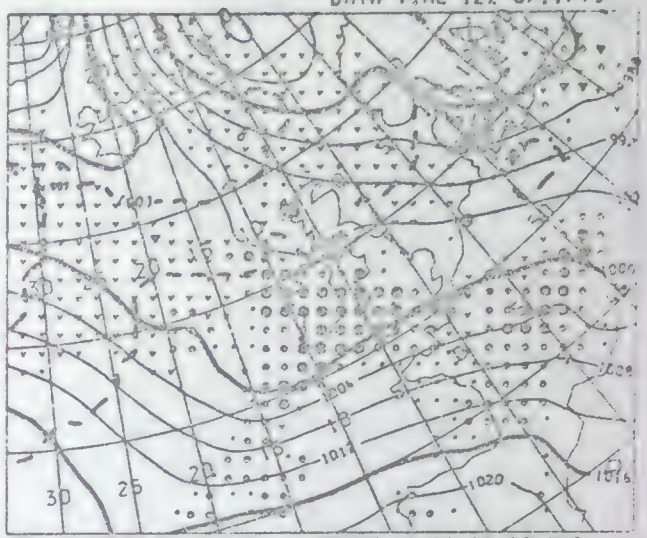
12HR FORECAST

VALID AT 0Z 7/11/79
DATA TIME 12Z 6/11/79

SURFACE PRESSURE AND PRECIPITATION

18HR FORECAST

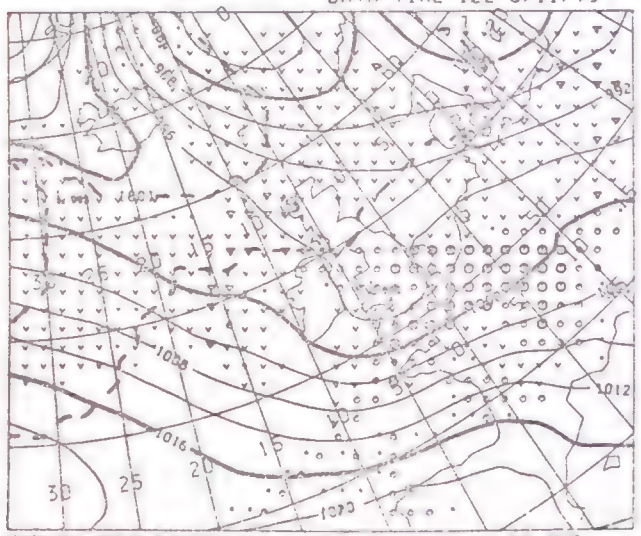
VALID AT 6Z 7/11/79
DATA TIME 12Z 6/11/79



SURFACE PRESSURE AND PRECIPITATION

24HR FORECAST

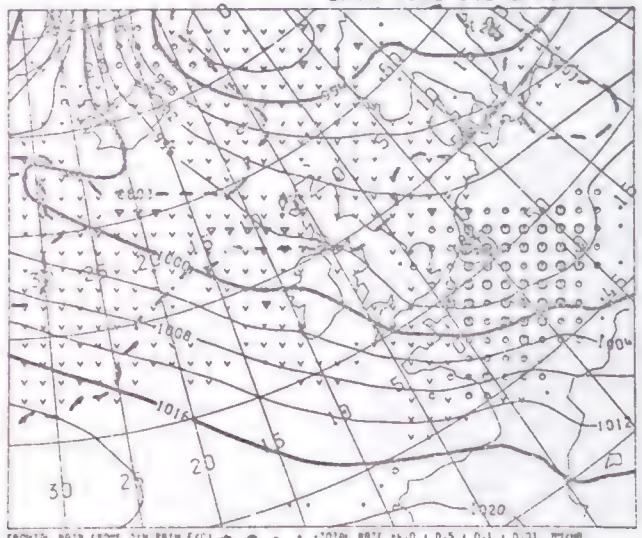
VALID AT 12Z 7/11/79
DATA TIME 12Z 6/11/79



SURFACE PRESSURE AND PRECIPITATION

30HR FORECAST

VALID AT 18Z 7/11/79
DATA TIME 12Z 6/11/79

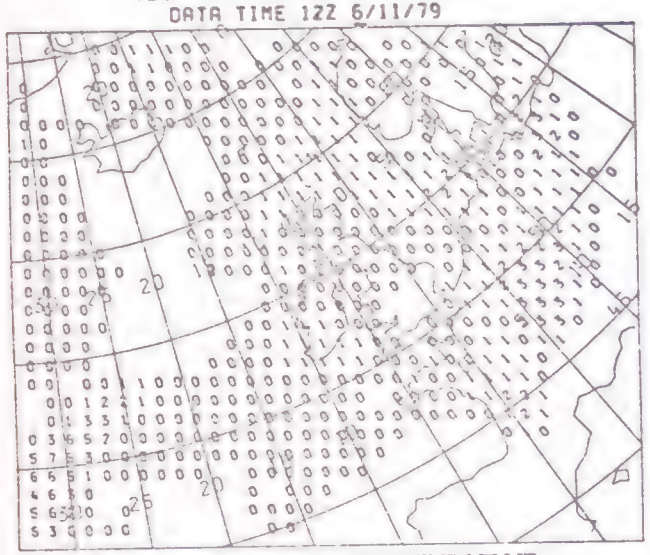


SURFACE PRESSURE AND PRECIPITATION

36HR FORECAST

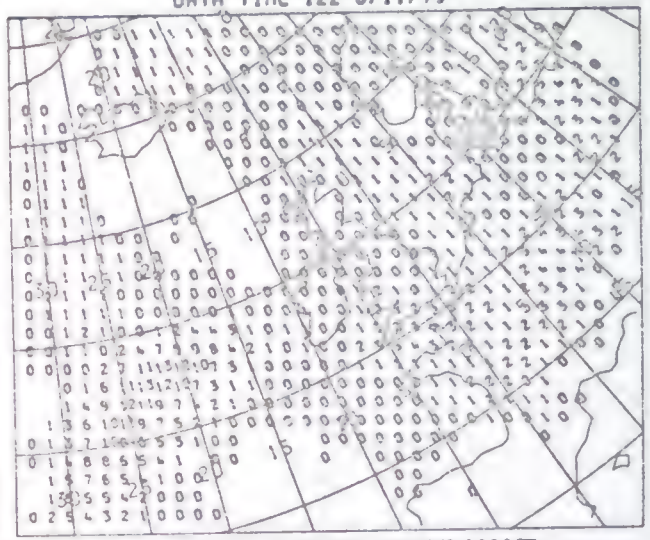
VALID AT 0Z 8/11/79
DATA TIME 12Z 6/11/79

T+0 TO T+6 ACCUMULATED RAINFALL
12Z TO 18Z 6/11/79 (TUESDAY)
DATA TIME 12Z 6/11/79



KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+6 TO T+12 ACCUMULATED RAINFALL
18Z TO 0Z 6/11/79 (TUESDAY)
DATA TIME 12Z 6/11/79

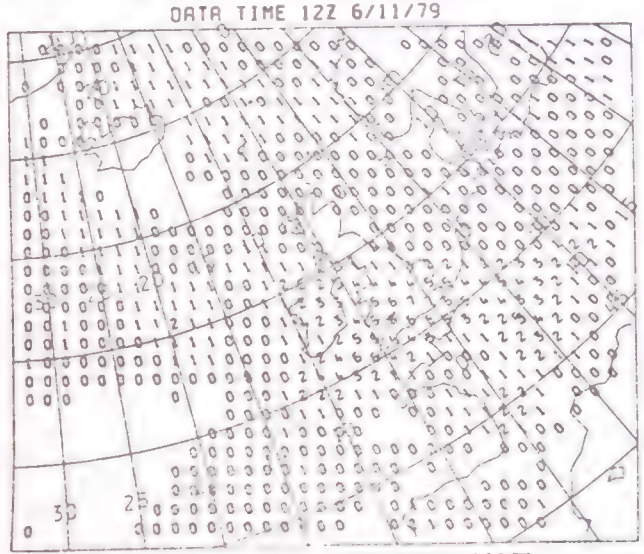


KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+12 TO T+18 ACCUMULATED RAINFALL
0Z TO 6Z 7/11/79 (WEDNESDAY)
DATA TIME 12Z 6/11/79

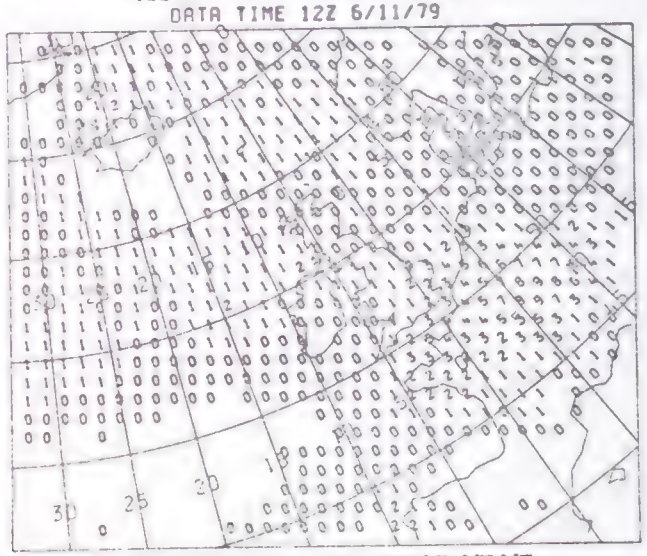
KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+18 TO T+24 ACCUMULATED RAINFALL
6Z TO 12Z 7/11/79 (WEDNESDAY)
DATA TIME 12Z 6/11/79



KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+24 TO T+30 ACCUMULATED RAINFALL
12Z TO 18Z 7/11/79 (WEDNESDAY)
DATA TIME 12Z 6/11/79



KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+30 TO T+36 ACCUMULATED RAINFALL
18Z TO 0Z 7/11/79 (WEDNESDAY)
DATA TIME 12Z 6/11/79

KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

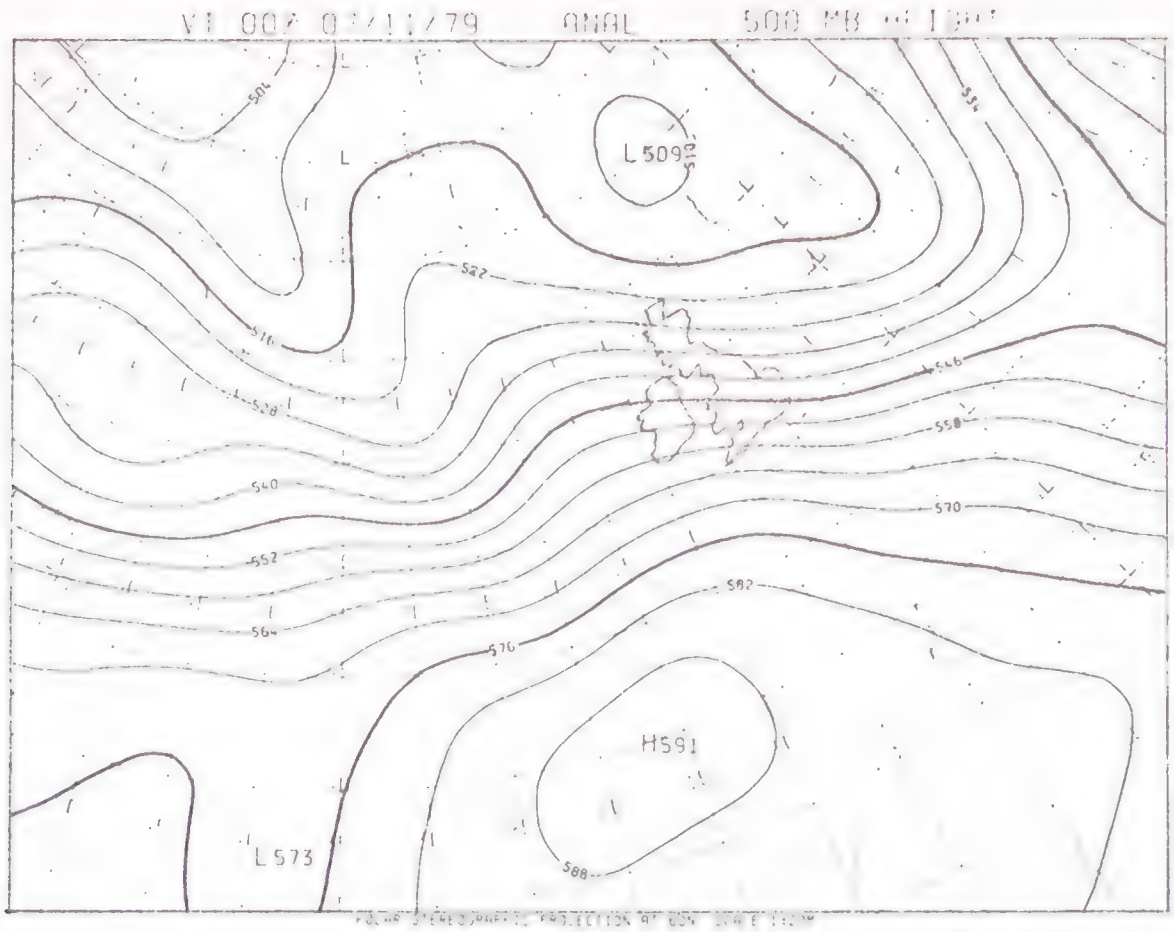


CHART 16

CFO

VT 00Z 07/11/79 ANAL SURFACE PRESSURE (4MB INT)

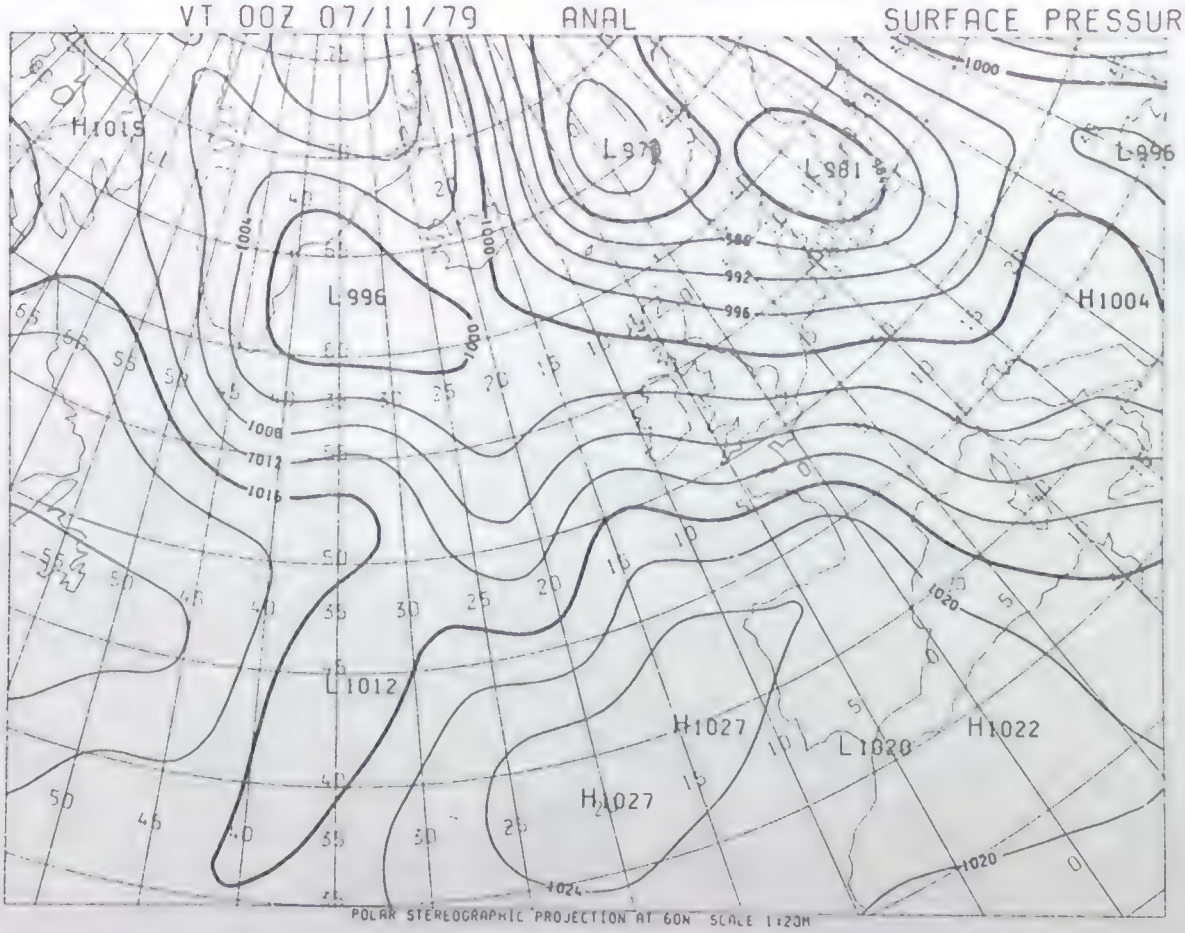


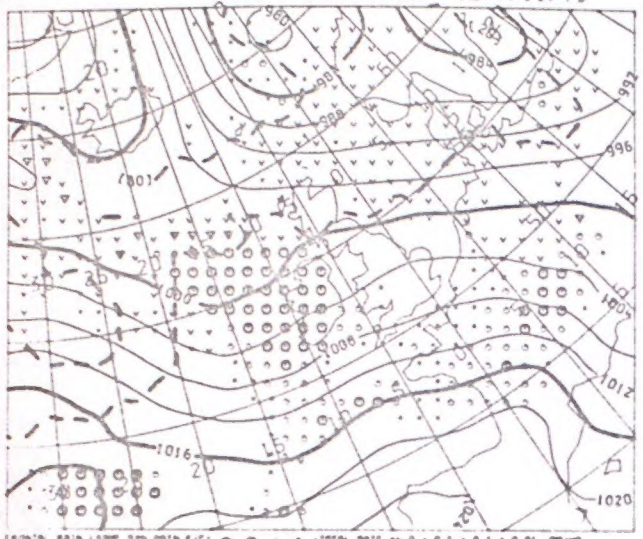
CHART 16

CFO

SURFACE PRESSURE AND PRECIPITATION

6HR FORECAST

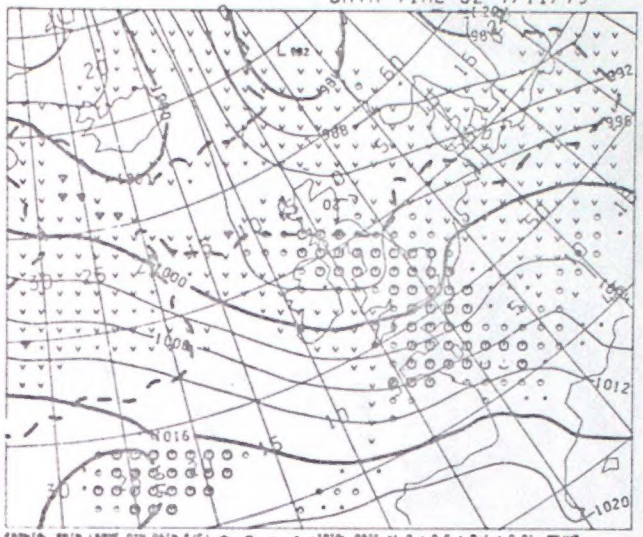
VALID AT 6Z 7/11/79
DATA TIME 0Z 7/11/79



SURFACE PRESSURE AND PRECIPITATION

12HR FORECAST

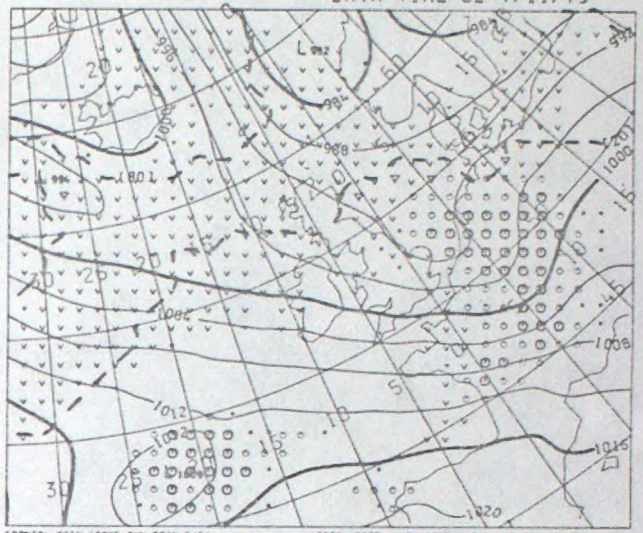
VALID AT 12Z 7/11/79
DATA TIME 0Z 7/11/79



SURFACE PRESSURE AND PRECIPITATION

18HR FORECAST

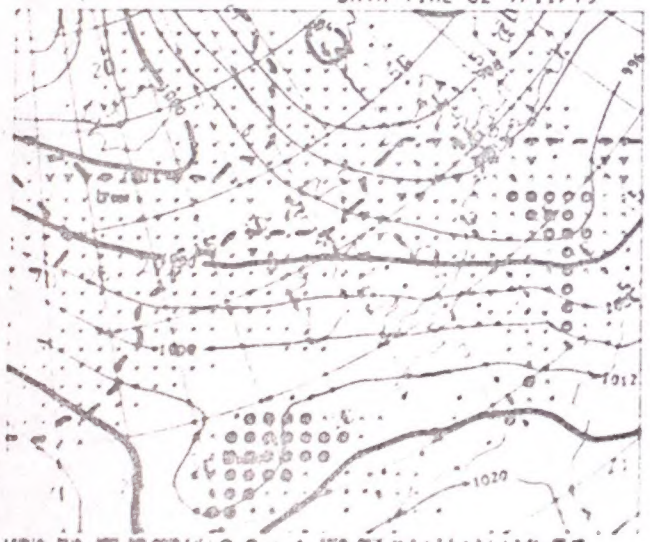
VALID AT 18Z 7/11/79
DATA TIME 0Z 7/11/79



SURFACE PRESSURE AND PRECIPITATION

24HR FORECAST

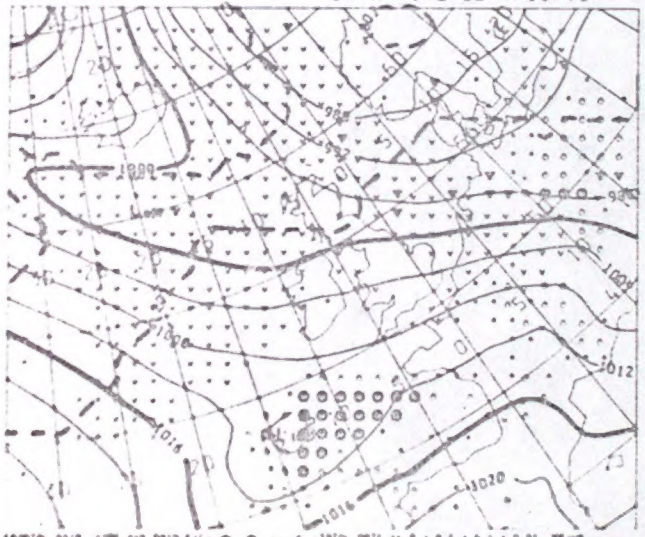
VALID AT 0Z 8/11/79
DATA TIME 0Z 7/11/79



SURFACE PRESSURE AND PRECIPITATION

30HR FORECAST

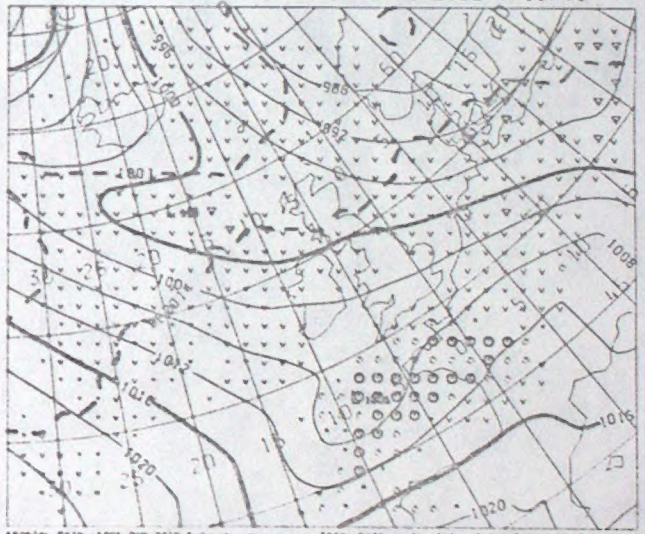
VALID AT 6Z 8/11/79
DATA TIME 0Z 7/11/79



SURFACE PRESSURE AND PRECIPITATION

36HR FORECAST

VALID AT 12Z 8/11/79
DATA TIME 0Z 7/11/79



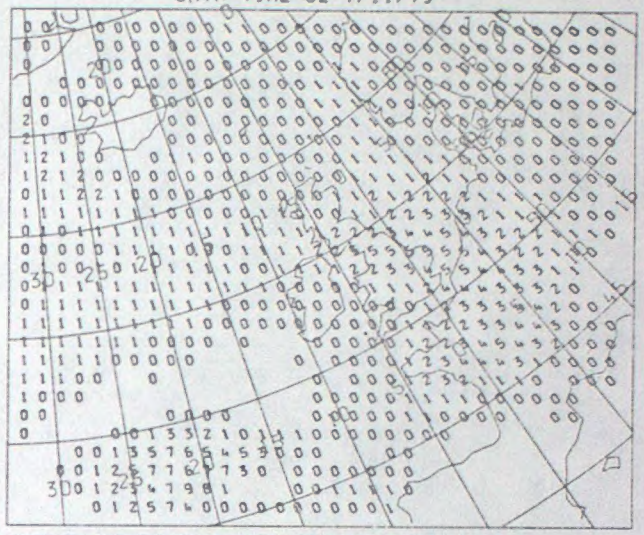
T+0 TO T+6 ACCUMULATED RAINFALL
0Z TO 6Z 7/11/79 (WEDNESDAY)
DATA TIME 0Z 7/11/79

KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+6 TO T+12 ACCUMULATED RAINFALL
6Z TO 12Z 7/11/79 (WEDNESDAY)
DATA TIME 0Z 7/11/79

KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+12 TO T+18 ACCUMULATED RAINFALL
12Z TO 18Z 7/11/79 (WEDNESDAY)
DATA TIME 0Z 7/11/79

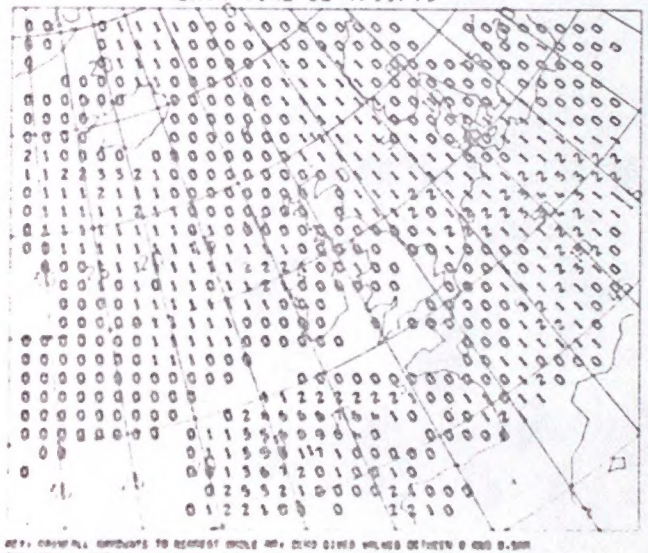


KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+18 TO T+24 ACCUMULATED RAINFALL
18Z TO 0Z 7/11/79 (WEDNESDAY)
DATA TIME 0Z 7/11/79

KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+24 TO T+30 ACCUMULATED RAINFALL
0Z TO 6Z 8/11/79 (THURSDAY)
DATA TIME 0Z 7/11/79



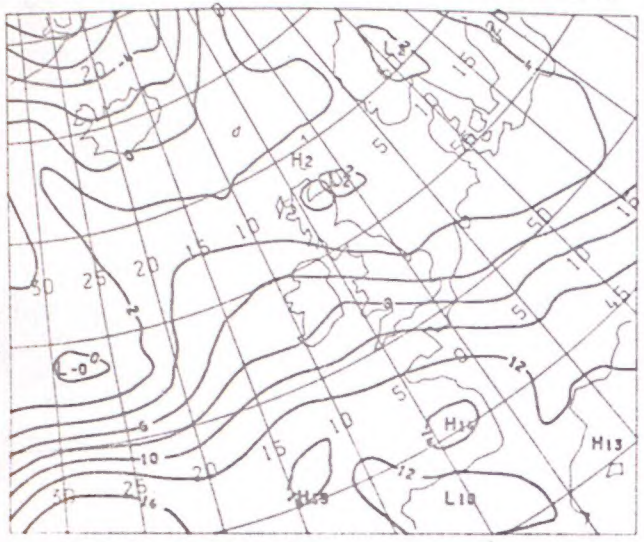
KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

T+30 TO T+36 ACCUMULATED RAINFALL
6Z TO 12Z 8/11/79 (THURSDAY)
DATA TIME 0Z 7/11/79

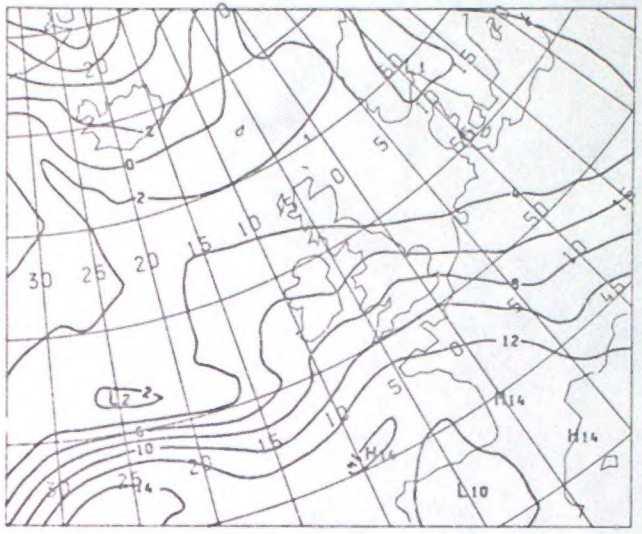
KEY: RAINFALL AMOUNTS TO NEAREST WHOLE MM: ZERO GIVES VALUES BETWEEN 0 AND 0.5MM
MAP SCALE: 1:20M

DT 00Z 07/11/79 WET BULB POTENTIAL TEMPERATURE 850 MB

06HR FORECAST VT 6Z 07/11/79



12HR FORECAST VT 12Z 07/11/79



18HR FORECAST VT 18Z 07/11/79

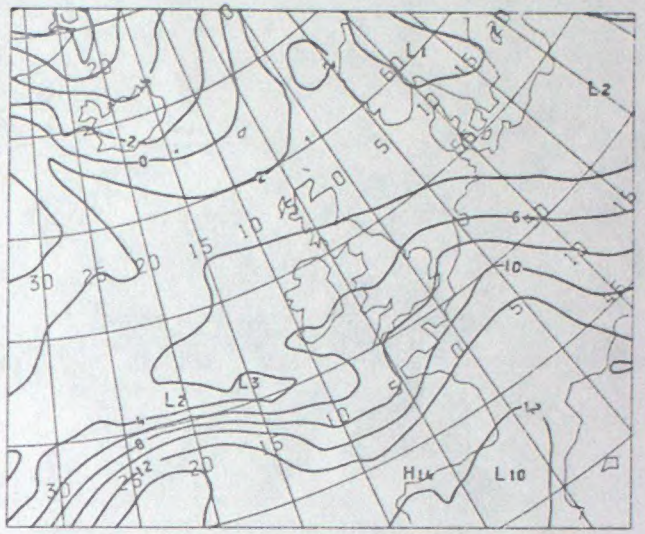
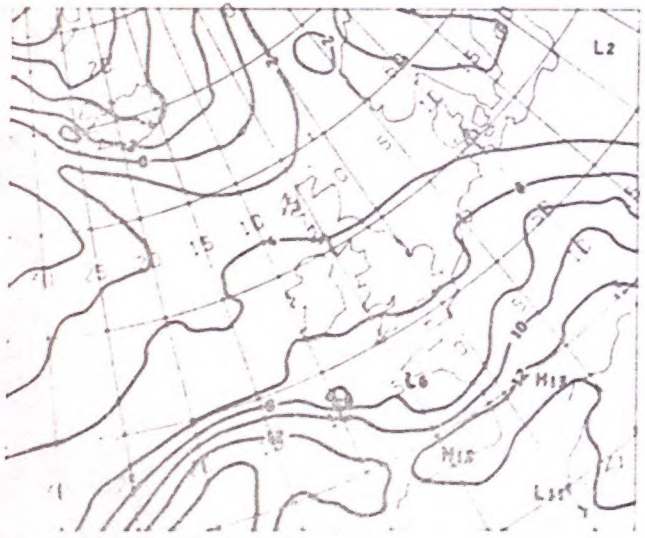
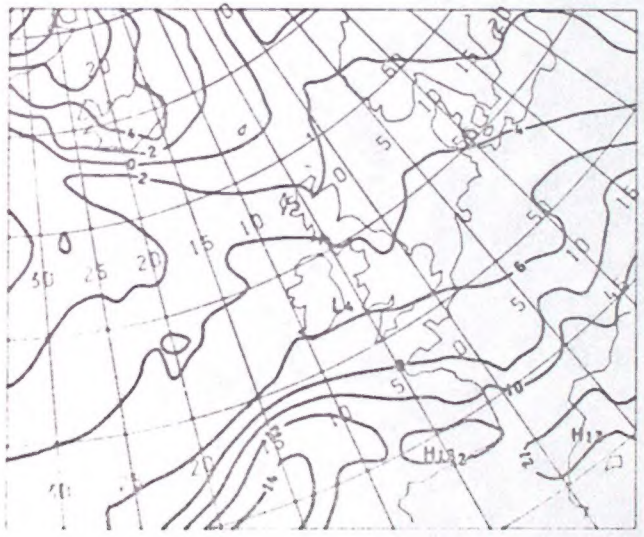


CHART 60 SCALE 1:20M

24HR FORECAST VT 00Z 08/11/79



30HR FORECAST VT 6Z 08/11/79



36HR FORECAST VT 12Z 08/11/79

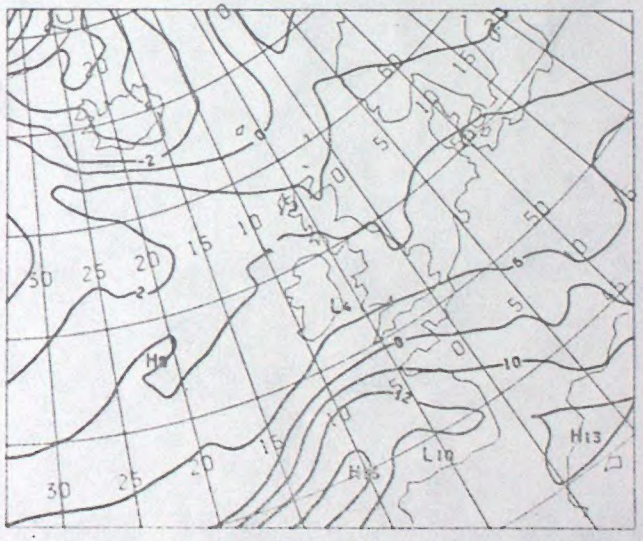
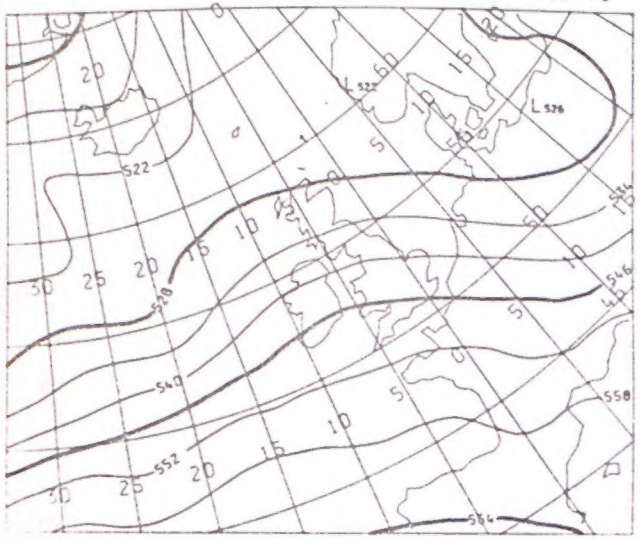


CHART 60 SCALE 1:20M

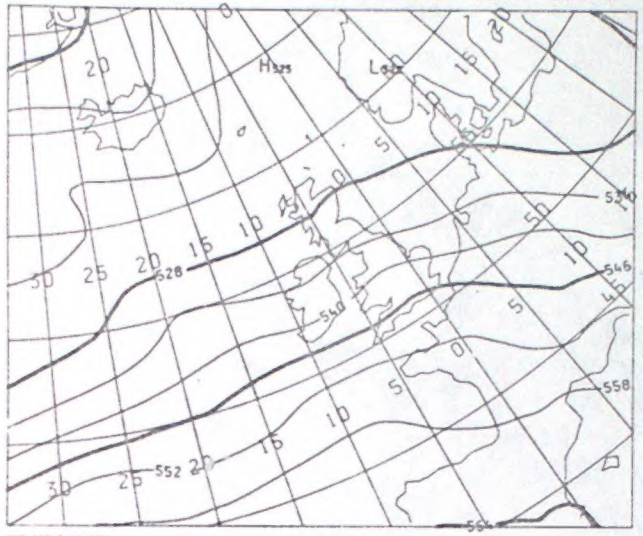
1000-500 MB THICKNESS (DM)

6HR FORECAST VALID AT 6Z 7/11/79
DATA TIME 0Z 7/11/79



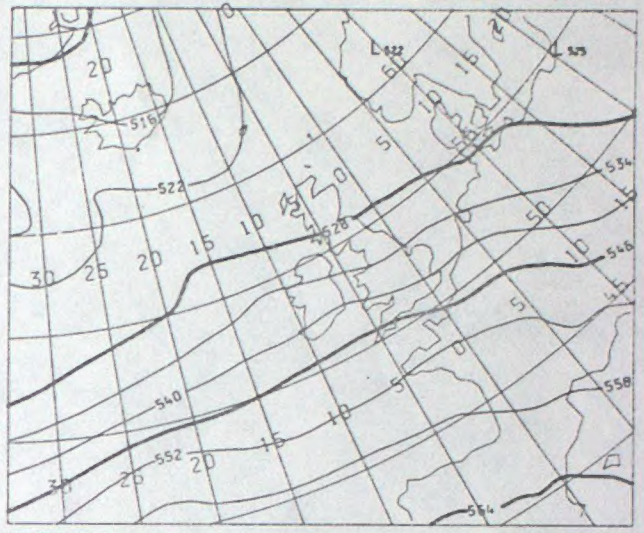
1000-500 MB THICKNESS (DM)

12HR FORECAST VALID AT 12Z 7/11/79
DATA TIME 0Z 7/11/79



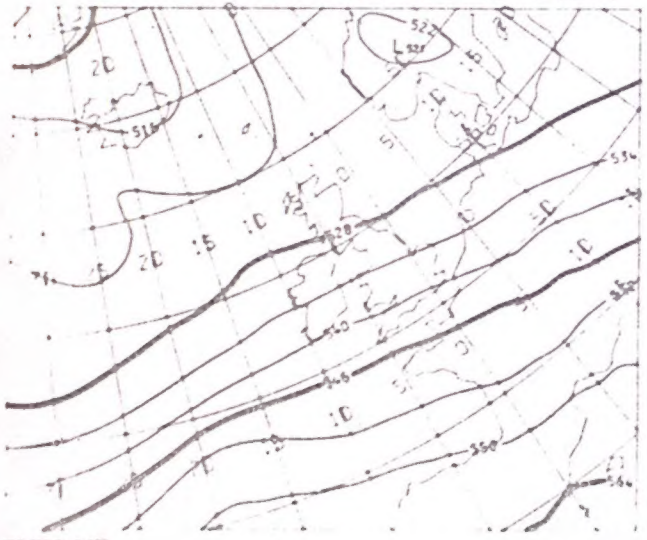
1000-500 MB THICKNESS (DM)

18HR FORECAST VALID AT 18Z 7/11/79
DATA TIME 0Z 7/11/79



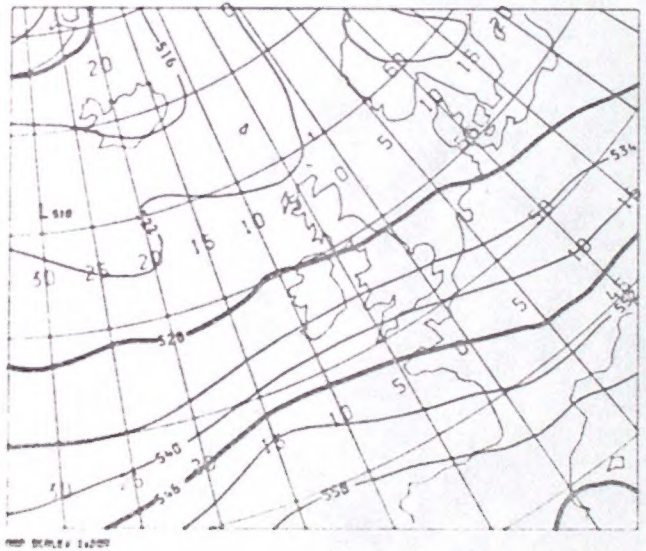
1000-500 MB THICKNESS (DM)

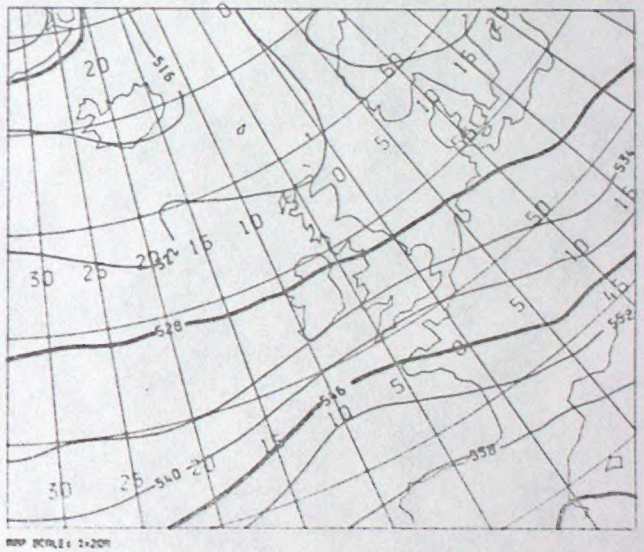
24HR FORECAST VALID AT 0Z 8/11/79
DATA TIME 0Z 7/11/79



1000-500 MB THICKNESS (DM)

30HR FORECAST VALID AT 6Z 8/11/79
DATA TIME 0Z 7/11/79



1000-500 MB THICKNESS (DM)

36HR FORECAST VALID AT 12Z 8/11/79
DATA TIME 0Z 7/11/79